Transit Temperatures and Quality Of Fresh Vegetables Shipped In An Experimental and a Commercial Van Container To The Far East

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PREFACE

One of the most important missions of the Agricultural Research Service (ARS) is the development, evaluation, and demonstration of improved methods of moving perishable food products to domestic and overseas markets. Our goal is to provide better environmental conditions for the products to protect their inherent quality and to reduce physical damage, spoilage losses, and transport, handling, and refrigeration costs.

The research reported here is part of that effort. It covers the first overseas shipping test with an experimental refrigerated van container developed by ARS scientists and engineers in cooperation with private industry. The van has been evaluated previously in a series of laboratory and domestic shipping experiments by highway and railroad transport. The container derives its high level of performance from a more efficient method of interfacing the refrigeration system with the load mass. The developmental work on the container was guided by Philip L. Breakiron, Chief, Transportation and Packaging Research Laboratory, Agricultural Marketing Research Institute, Beltsville, Md., Project Coordinator, and William F. Goddard, Jr., mechanical engineer, Orlando, Fla., Project Engineer.

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Appreciation is expressed to many others within the above organizations who helped with various aspects of this test.

I appreciate the valuable assistance of R. H. Hinds, Jr., and R. T. Hinsch, Agricultural Research Service, U.S. Department of Agriculture (USDA), Fresno, Calif., in instrumenting the test vans and in making arrangements with the Military Establishment.

Engineering aspects of the USDA experimental van are available from:

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SUMMARY

Transit temperatures and arrival condition of mixed vegetables (cabbage, carrots, celery, and lettuce) were determined in produce shipped in a U.S. Department of Agriculture (USDA) experimental van container and a commercial refrigerated van container from San Francisco, Calif., to Pusan, South Korea. The test was made in cooperation with the U.S. Department of Defense.

The USDA experimental van, tightly stacked with packages of produce in a solid load pattern, provided commodity temperatures comparable to those in a commercial refrigerated van that had a spaced load with air channels for air circulation around the packages.

Solid load patterns are faster and easier to load than spaced load patterns and allow more packages to be placed in a van container. Solid loads, however, can only be used in vans with refrigeration and air distribution systems designed to force refrigerated air through the package. Otherwise, excessive temperatures would occur within the load, accompanied by deterioration of product.

Quality of the cabbage, carrots, and celery shipped in the two vans was good at destination, but lettuce suffered losses from decay in both vans.

INTRODUCTION

The increase in exports of U.S. farm products to foreign countries in recent years has improved our balance of payments. "Between 1963 and 1973, agricultural exports have made a total net contribution to the nation's balance of payments of $22.9 billion—roughly 5 times greater than the net contribution of non-farm exports."[1] Although grains are the most important farm commodity exported, exports of fresh fruits and vegetables are also increasing.

Fresh fruits and vegetables are highly perishable and require special handling from harvest to consumption. Maintenance of proper temperatures is of greatest importance during the postharvest period.

Although great strides have been made in developing refrigeration equipment for transporting fresh produce, improper temperatures

[1] ANONYMOUS. WHY EXPORT FARM GOODS? "USDA" 33 (21): 1–2. 1974.

(either too warm or freezing) are responsible for most losses of produce at overseas markets. USDA researchers have been working on a refrigerated van container[2] for fresh produce that incorporates a forced-air principle.

Transit temperatures and arrival condition of mixed vegetables were compared in this experimental van with those in a commercial refrigerated van during transport to overseas markets.

EQUIPMENT AND METHODS

Two 40-foot refrigerated vans, each with a mixed load of fresh produce, were accompanied by the author from California to Pusan, South Korea. One was an experimental van designed by USDA researchers in cooperation with manufacturers, whereas the other was a new, commercial-type van used by the cooperating ocean carrier.

The principal difference between the two vans tested was the air circulation system. In the USDA van, cold air passes through enclosed ducts at the ceiling, down sidewall flues, through the floor extrusions (which run crosswise in the van), then up through the load, and back to the air return at the top of the front bulkhead.[3] In the commercial van, the cold air moves from above the perforated plenum above the load, down through the load to the floor extrusions (which run lengthwise in the van), and back to the air return at the bottom of the front bulkhead. Most commercial refrigerated vans have a cloth or plastic duct at the ceiling for air distribution rather than the perforated metal plenum that was in the commercial van used in this test. The USDA experimental van had squirrel cage fans and a pressurized air circulation/distribution system. The commercial van had prop fans and a nonpressurized air circulation system. In figure 1, the USDA van is shown being removed from the ship at Pusan, South Korea.

Transit temperatures and atmospheres, oxygen (O_2), and carbon dioxide (CO_2) were measured at intervals in the two vans from time of loading until unloading. Temperatures were measured with a potentiometer and thermocouples, which had been placed in the produce during loading. Six thermocouples were used for each of the four commodities in each van. Two thermocouples were in the top layer, two in the middle layer, and two in the bottom layer. Air temperatures were also measured with thermocouples placed above and below the produce.

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FIGURE 1.—USDA experimental van container being removed from ship at Pusan, South Korea.

O_2 and CO_2 were measured in each van with Fyrite gas analyzers. The air samples were drawn through quarter-inch plastic tubing extending from each van. No attempt was made to modify the atmosphere in either van.

The vegetables used in the test were harvested and packed by commercial crews at the following locations in California on the indicated 1974 dates: Cabbage, Watsonville, May 28; carrots, Holtville, May 25; celery, Oxnard,

[2] Hereafter referred to as "van."

[3] GODDARD, W. F. THE FLOOR—A COMMON DENOMINATOR FOR REFRIGERATED TRANSPORT PROBLEMS. Internatl. Inst. Du Froid—Internatl. Inst. Refrigeration—Com. D2, Wageningen, The Netherlands. Pp. 39–49. 1974.

May 24; and lettuce, Salinas, May 28. All the vegetables were assembled at Salinas and were loaded into the vans on May 28. The load in each van consisted of 139 cartons of cabbage, 100 cartons of carrots, 145 wirebound crates of celery, and 139 cartons of lettuce.

Solid load patterns were used for each of the four commodities in the USDA van in which the relatively high static pressure forces air through a tightly stacked load. Spaced load patterns, normally used by the military, were used in the commercial van. A modified bonded block pattern was used for the cartons, and a pigeonhole pattern for the wirebound crates in this van.[4]

After loading, the vans were trucked to San Francisco where they were held at the ship line terminal until the night of May 31 when they were placed aboard a container ship. The ship left San Francisco June 1 and arrived at Pusan June 15, after making intermediate stops at Yokohama (June 12) and Kobe (June 13), Japan. The produce was unloaded from the two test vans at Pusan on June 17.

Sample boxes of produce were recovered from each van for evaluation at destination. These sample boxes were taken from about the middle layer of a midsection stack of each commodity loaded in each van. Half of each test box of produce was evaluated as soon after arrival as possible (after 1 night at 34° F), and the other half was evaluated after holding an additional 3 days at 50°.

The rating scale used to evaluate the overall general appearance of the vegetables was: 1, extremely poor; 3, poor; 5, fair; 7, good; and 9, excellent. All defects were rated on the following scale: 1, none; 2, trace; 3, slight; 4, moderate; and 5, severe.

RESULTS

Temperatures in Transit

Cabbage

Cabbage temperatures averaged about 43° F at time of loading, cooled to about 36° in each van during the first 24 hours (fig. 2), and averaged 36° for the entire trip in the USDA van and 35° in the commercial van.

Temperatures of cabbage were very uniform throughout the load in both vans. Differences between the minimum and maximum temperatures of the cabbage averaged 2° F in the USDA van and 1° in the commercial van.

After June 10, temperatures of the cabbage in both vans decreased by 3° F, and they remained lower during the remainder of the trip. This decrease in commodity temperature coincided with increases in ambient temperature that occurred when the ship entered the warm Japan current (fig. 3).

Carrots

The carrots were warm at time of loading, averaging 54° F in the USDA van and 52° in the commercial van (fig. 2). Cooling of the carrots was relatively slow in both vans, probably because they were packed in fiberboard boxes with nonperforated polyethylene liners, which kept refrigerated air from direct contact with the carrots.

The carrots cooled to 40° F about one day sooner in the USDA van than in the commercial van (3 versus 4 days). Temperatures within the load of carrots were more uniform in the USDA van than in the commercial van. The average minimum and maximum temperatures of the carrots were 38° and 41° in the USDA van and 38° and 43° in the commercial van. Average temperatures of the carrots for the entire transit period was 39° in the USDA van and 40° in the commercial van.

Temperatures of the carrots, as with the cabbage, decreased in both vans after June 10.

Celery

Celery temperatures averaged 47° F in both vans at time of loading, although some temperatures reached 51° (fig. 2). Celery in both

[4] STEWART, J. K., BONGERS, A., and HINDS, R. H. SPACED LOAD PATTERNS FOR IMPROVED TEMPERATURE CONTROL IN EXPORT SHIPMENTS OF LETTUCE. U.S. Dept. Agr. Market. Res. Rpt. 1051, 9 pp. 1976.

vans cooled to about 38° in less than one day, and temperatures during transit were equally uniform with the average maximum and minimum differing by only 2°. The average trip temperature for the celery was 35° in the USDA van and 36° in the commercial van.

Celery temperatures in both vans decreased slightly after June 10.

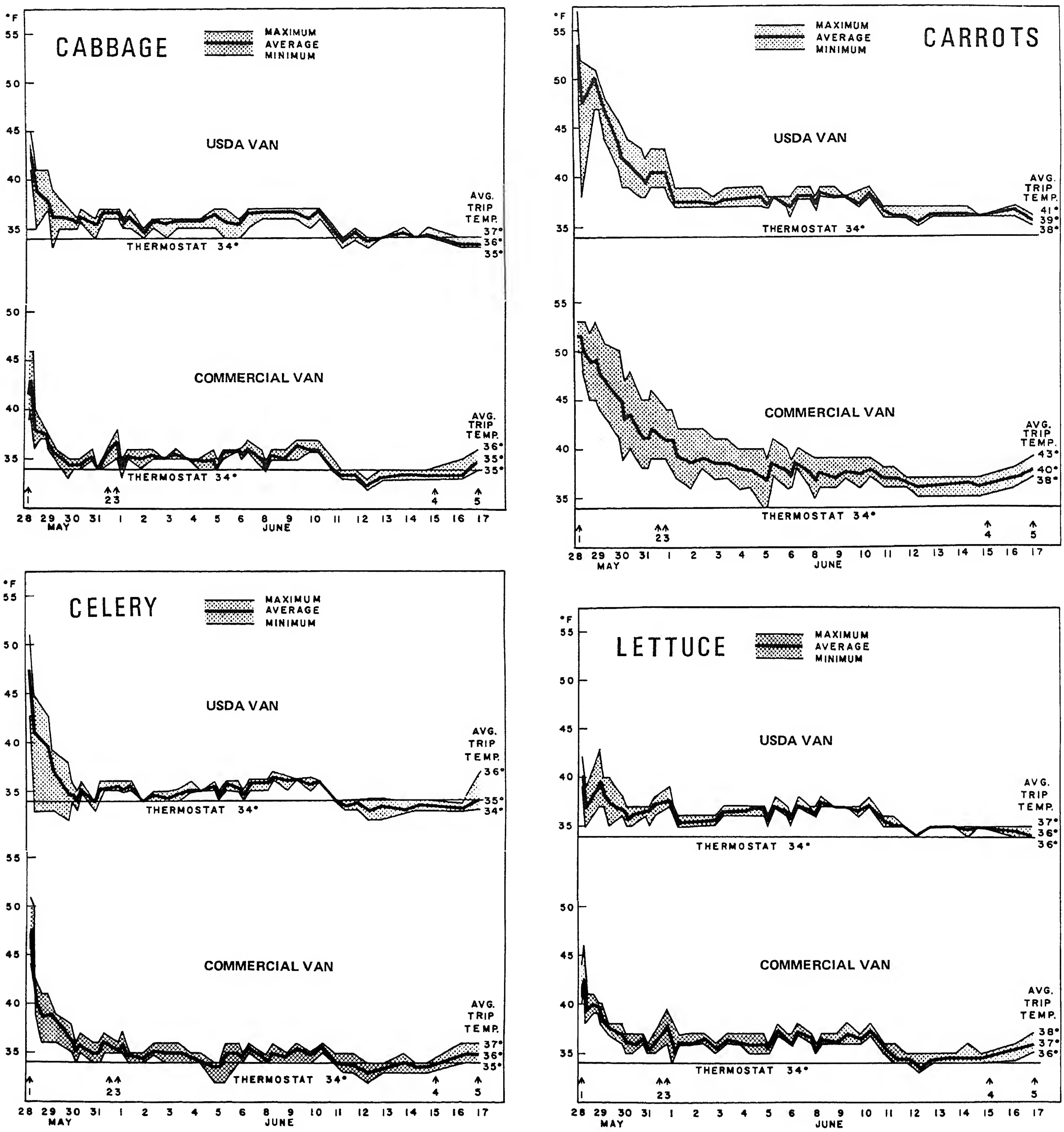

FIGURE 2.—Transit temperatures of cabbage, carrots, celery, and lettuce shipped in mixed loads in two types of refrigerated van containers from California to Pusan, South Korea. (1) Vans loaded at Salinas, Calif. (2) Vans placed on ship at San Francisco. (3) Ship left San Francisco. (4) Vans removed from ship at Pusan, South Korea. (5) Produce removed from vans.

Lettuce

Lettuce temperatures at time of loading averaged about 41° F and were uniform during transit in both vans (fig. 2). Lettuce temperatures ranged from an average minimum of 36° to an average maximum of 37° in the USDA van, and from 36° to 38°, respectively, in the commercial van.

A temperature response similar to that for the other commodities occurred after June 10.

Air temperatures

Return air temperatures, measured by a thermocouple in the return airstream, averaged 36° F in each van (fig. 3). Air discharge temperatures, measured by a thermocouple at opening of the distribution duct or plenum, averaged 36° in the USDA van and 35° in the commercial van. Air temperatures at the return fluctuate much less than those at the discharge because the return air is buffered as it passes through the load.

The temperature of both the discharge and return air decreased slightly after June 10, which is reflected in the temperatures of the produce given above.

The air temperatures inside the vans, as indicated in figure 3, represent readings taken twice daily and do not reflect all variations due to cycling of the refrigeration system. The latter temperatures were obtained for both vans on June 11 by measuring the discharge air temperatures at 1- or 2-minute intervals over 1 to 2 hours (fig. 4). The USDA van completed a cycle in about 21 minutes, with the air cooling (compressor on) for about 7 minutes and warming (compressor off) for about 14 minutes. The length of the cycle of the commercial van was 44 minutes, with the air cooling for about 17 minutes and warming for 27 minutes. Therefore, the USDA van had about twice as many refrigeration cycles in a given period as the commercial van.

The average minimum and maximum air discharge temperatures during cycling of the refrigeration system in the USDA van were 33° and 39° F, respectively, and in the commercial van were 29° and 38°, respectively.

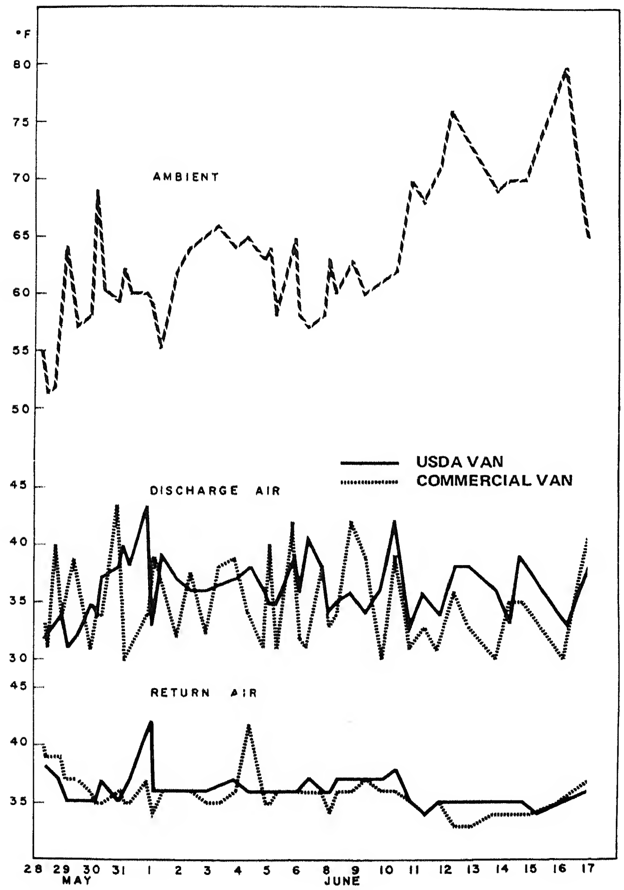

FIGURE 3.—Ambient, discharge, and return air temperatures taken twice daily during export of two refrigerated van containers of mixed produce from California to Pusan, South Korea.

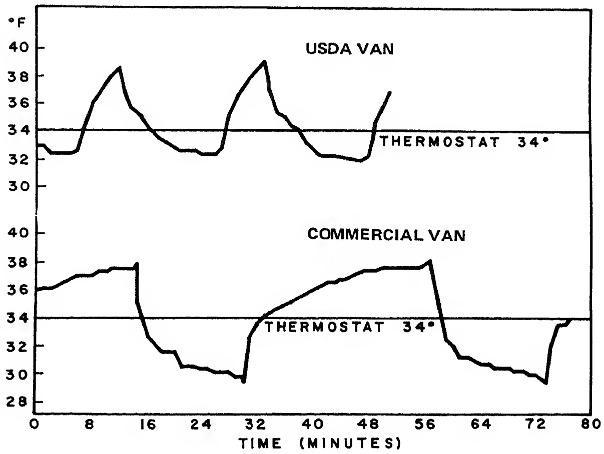

FIGURE 4.—Discharge air temperatures taken at 1- or 2-minute intervals in two refrigerated van containers of mixed vegetables on June 11, 1974, during export from California to Pusan, South Korea.

Atmospheres in Transit

O_2 concentrations averaged between 20 and 21 percent and CO_2 concentrations averaged less than 1 percent in both vans during the trip. Therefore, the O_2 level was not low enough to benefit the produce, and the CO_2 was neither high enough to benefit nor harm the produce. Atmosphere data are not shown because no significant modification of O_2 or CO_2 concentrations occurred.

Produce Quality

Cabbage

No decay was found in the cabbage from either van at either examination (table 1). The principal defects were dark discoloration and wilting of the outer leaves. There was no difference in quality of the cabbage from the two vans at the first examination.

Before the outer leaves were removed, the cabbage was rated "good" for overall appearance, and after the discolored and wilted leaves were removed, it was rated "good to excellent."

At the second examination, there was still no appreciable difference between test lots of cabbage shipped in the two vans. Before removal of the outer leaves, the cabbage was rated "fair to good," and after the leaves were removed, it was rated "good."

TABLE 1—*Quality of U.S.-grown cabbage after transport to South Korea in a USDA experimental van container and in a commercial van container* [1]

Examination[2] and van container	Appearance: Before trimming	Appearance: After trimming	Decay[3]
	Rating[4]	*Rating*[4]	*Percent*
First examination			
USDA	6.8	8.1	0
Commercial	7.0	8.1	0
Second examination			
USDA	6.2	7.4	0
Commercial	5.8	7.2	0

[1] Average of 2 test boxes per van, each containing about 2 dozen heads. Half the cabbage from each test box was evaluated at each of the 2 examinations.

[2] First examination was made as soon as possible after arrival in South Korea (June 18), and the second examination was made after the cabbage had been held an additional 3 days at 50° F.

[3] Heads with a trace or more decay.

[4] Rating scale of 1 to 9 in which 1 = extremely poor, 3 = poor, 5 = fair, 7 = good, 9 = excellent.

Carrots

The carrots from both vans were in very good condition at the first examination. They were rated "good to excellent" in both turgidity and general appearance (table 2). Carrots from both vans had become slightly less turgid by the second exam, but they were still in good condition. No decay was present in the carrots at either examination.

Celery

Celery from both vans showed some yellowing of the leaves and wilting, but no decay of commercial significance. A trace of decay was present in celery from the USDA van at the first examination (table 3). Celery from one of the four test boxes (from the conventional van) was severely wilted at the first examination. Because celery from the other three boxes was turgid, this one box may have been subjected to more adverse conditions than the others at shipping point. The poor condition of this box of celery lowered the average appearance and turgidity ratings of the lots from the commercial van at both the first and second examination. Therefore, even though the quality ratings are lower for the celery from the commercial than from the USDA van, the difference should not be attributed to temperature and humidity conditions within the vans.

Lettuce

Lettuce deteriorated during transit more than the other vegetables. Decay occurred in lettuce from both vans. Although numerical differences in quality are shown for lettuce from the two vans (table 4), these differences are attributed to normal variation among lots and not to the vans. For example, at the first examination there was more decay in the commercial than in the USDA van, whereas at the second examination, the reverse was true. A few heads were not considered salable because decay had progressed too far. Quality of the lettuce would not be expected to differ greatly in the two vans since transit temperatures were essentially the same.

TABLE 2.—*Quality of U.S.-grown carrots after transport to South Korea in a USDA experimental van container and in a commercial van container* [1]

Examination [2] and van container	Appearance	Turgidity	Decay [3]
	Rating [4]	*Rating* [4]	*Percent*
First examination			
USDA	8.0	8.0	0
Commercial	8.0	8.0	0
Second examination			
USDA	7.5	7.0	0
Commercial	7.0	7.0	0

[1] Average of 2 test boxes per van each containing about 50 pounds of carrots. About half of the carrots from each box were evaluated at each of the 2 examinations.

[2] First examination was made as soon as possible after arrival in South Korea (June 18), and the second examination was made after the carrots had been held an additional 3 days at 50° F.

[3] Heads with a trace or more decay.

[4] Rating scale of 1 to 9 in which 1 = extremely poor, 3 = poor, 5 = fair, 7 = good, 9 = excellent.

TABLE 3.—*Quality of U.S.-grown celery after transport to South Korea in a USDA experimental van container and in a commercial van container* [1]

Examination [2] and van container	Overall appearance	Leaf color	Turgidity	Decay [3]
	Rating [4]	*Rating* [4]	*Rating* [4]	*Percent*
First examination				
USDA	7.9	7.8	8.1	8
Commercial	5.5	7.5	5.6	0
Second Examination				
USDA	5.8	6.3	5.8	0
Commercial	5.4	6.0	5.2	0

[1] Average of 2 test boxes per van, each containing 3 dozen heads (except one test box which contained 2 dozen heads). Half of the heads from each box were evaluated at each of the 2 examinations.

[2] The first examination was made as soon as possible after arrival in South Korea (June 18) and the second examination was made after the celery had been held an additional 3 days at 50° F.

[3] Heads with a trace or more decay.

[4] Rating scale of 1 to 9 in which 1 = extremely poor, 3 = poor, 5 = fair, 7 = good, 9 = excellent.

TABLE 4.—*Quality of U.S.-grown lettuce after transport to South Korea in a USDA experimental van container and in a commercial van container* [1]

Examination [2] and van container	Salable heads: Without retail trimming	Salable heads: After retail trimming	Appearance before trimming	Heads with decay rated [3]: Trace or more	Heads with decay rated [3]: Slight or more
	Percent	*Percent*	*Rating* [4]	*Percent*	*Percent*
First examination					
USDA	100	100	7.2	4	0
Commercial	83	96	6.5	17	17
Second examination					
USDA	83	96	5.4	46	17
Commercial	86	91	5.6	43	10

[1] Average of 2 test boxes per van, each containing 2 dozen heads of lettuce. Half of the lettuce from each test box was evaluated at each of the 2 examinations.

[2] First examination was made as soon as possible after arrival in South Korea (June 18), and the second examination was made after the lettuce had been held an additional 3 days at 50° F.

[3] Rating scale of 1 to 5 in which 1 = none, 2 = trace, 3 = slight, 4 = moderate, 5 = severe.

[4] Rating scale of 1 to 9 in which 1 = extremely poor, 3 = poor, 5 = fair, 7 = good, 9 = excellent.

DISCUSSION

Both the USDA experimental van and the commercial van performed well during the export test. However, in situations in which cooling was particularly difficult, as with the carrots in nonperforated, polyethylene liners, the experimental van cooled the load somewhat faster than the commercial van. Further, the experimental van provided uniform, satisfactory temperatures under conditions of tight-stacked, solid loads, whereas the commercial van required spaced load patterns for center-of-the-load cooling. Although the same number of packages were used in each van for this test, the experimental van could carry more packages with a solid pattern than a commercial van could with spaced load patterns.

Although crushing of packages was not a problem in this test, packages are less subject to crushing damage when stacked tight in register, as in the experimental van, than when space stacked as in the commercial van. Loading of a solid load is also simpler and faster than a spaced loading pattern, which appeals to loaders in California and Arizona, who are paid on a piecework basis.

The apparent correlation between increasing ambient temperatures and decreasing produce temperatures in these test vans needs further study. This phenomenon could lead to possible losses from freezing of fresh produce.

All four commodities in this test were warmer than desirable at time of loading, suggesting that when produce must be assembled for mixed loads, it should be held in coldrooms at recommended temperatures prior to transport.

One of the commodities in this test was harvested 4 days before loading, an undesirable practice for produce that is to be shipped overseas.

Decay losses in highly perishable lettuce were too high, suggesting that additional research should be devoted to improved handling and transport methods for this crop.

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